Simulation of high voltage pulse supply for Electric Vehicles using Full-Bridge DC-DC Converter

Deepak Sharma, Vijay Bhuria,

Abstract— The electric power and transportation industries are two major sectors for primary energy consumption on Earth. The proposed a DC-DC converter, convert low DC voltage (12V) to high DC voltage (36V) supplied to the electric system of pollution free electric vehicles, for this purpose, full-bridge DC-DC converter technology, is used to achieve the high efficiency, high performance, small size and lightweight through design of high frequency switching, transformer and RCD snubber. DC-DC Converters used in battery electric vehicles (BEVs), hybrid electric vehicles (BEVs), and fuel cell vehicles (FCVs). The simulations are carried out using simulink/MATLAB 7.7.0. (R2009a6.lnk)

***Index Terms*—Electric Vehicles, Full-Bridge DC-DC Converter, RCD Snubber**

I. Introduction

In order to make our environment green and pollution free "Electric Vehicles" plays an important role in our lives. Besides of that, an electric vehicle also helps in reducing global warming and helps in reducing the huge consumption of petroleum resources which are non-renewable. Now days most of the countries are headed towards the electric motor vehicles, since there is a huge investment in the internal combustion engine [2]

The main motto for developing the EV (Electric Vehicle) and HEV (Hybrid Electrical Vehicle) is to reduce the pollution generated by the hydrocarbon combustion and to save the non renewable source. Today there are so many technologies to generate electricity, but it is impossible to generate the non-renewable sources. It took millions and billions of years by earth to produce such type of source which are non-renewable [4]

The important thing is that, to run an electric vehicle there is a need of power source which can deliver the required amount to the electric motor. Instead of combustion engine in vehicles, here electric motors are used. Since there are batteries which are the primary energy-storage device in ground vehicles so instead of ac motor like in trains, a use of dc motor helps in this case. The biggest task is to supply this dc motor. Since the motor rating must be high so that it can bear the load and can run on good speed. Hence for such type of dc motor instead of a constant dc, a high voltage pulsating dc is feed to the motors. These high voltage pulses are generated by the pulse generators.

To develop a DC-DC converter which can convert high battery voltage into low DC voltage supplied to the electric system of the eco-friendly electric bus. As the electric bus parts have large capacity and the larger difference between input and output voltages comparing to those of the passenger cars, high capacity power converter is required. In order to implement the circuit, we have applied full-bridge converter topology. In order to achieve the high efficiency [7] Full-bridge topology is the most popular topology used in the power range of a few kilowatts (1–5 KW) for DC/DC converters [6]

II. CIRCUIT DESCRIPTION

Pulsed Power Supply Block Diagram

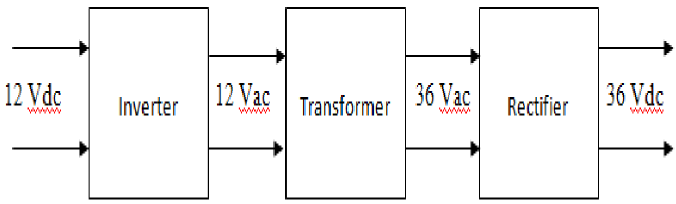

Fig 1.1 Block Diagram of Pulsed Power Supply [18]

High voltage pulsed power modulator Schematic Diagram

The DC - DC converter consist of three modules:

- Inverter (high frequency full bridge)
- Transformer (ferrite core based step-up)
- Rectifier (high frequency full bridge)

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ISSN: 2278 – 7798

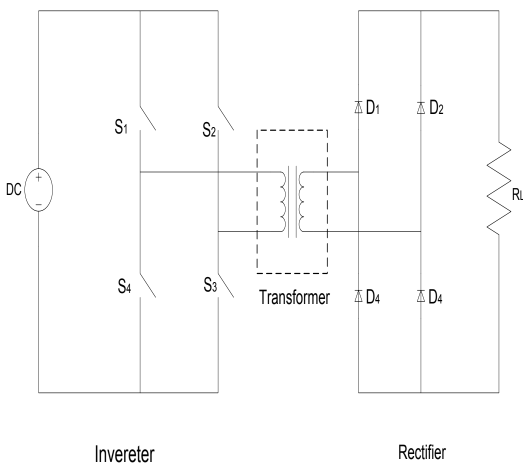

Fig. 1.2 Schematic diagram of High Voltage Pulsed Power Modulator [20]

High Frequency Full Bridge Inverter also known as ‘Static Power Converter’ that converts the DC sources to AC sources. This AC output can be obtained by the use of semiconductor switching device and controller circuit. Inverters are used in a wide range of applications, from small switched power supplies for a computer to large electric utility applications to transport bulk power like Voltage Compensator, UPS (uninterrupted power Supply), FACTS (Flexible AC Transmission System), ASD (Adjustable Speed Drive), Active Filters and etc [18]

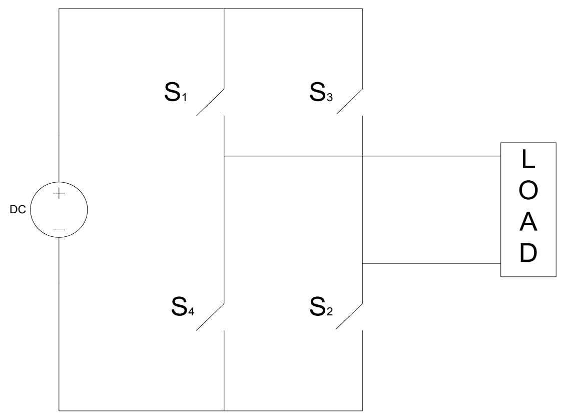

Fig. 1.3 Full Bridge DC to AC power circuit [17]

To obtain the AC output voltage, first switch S_1 and S_2 are turned on, hence we will get the positive cycle, later when switches S_3 and S_4 turned on will get the negative cycle. The output of the full bridge single phase inverter is given in figure 1.4:

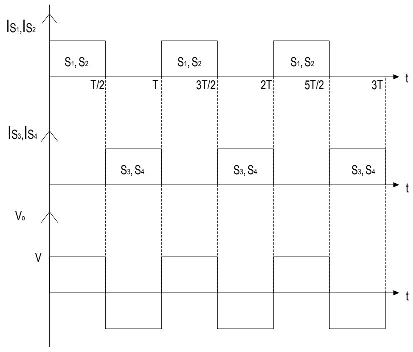

Fig. 1.4 Typical Gate Drive Pulses for Full Bridge Inverter Circuit [20]

High Frequency Full Wave Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as Rectification.

o Full wave rectifier

Full wave rectification converts both polarities of the input waveform to DC providing the higher mean output voltage. The rectifier circuit consists of four diodes for uncontrolled full bridge rectifier or four switches for controlled full bridge rectifier. The full bridge rectifier designed is an uncontrolled rectifier, the figure 1.5 shows a full bridge uncontrolled rectifier [17]

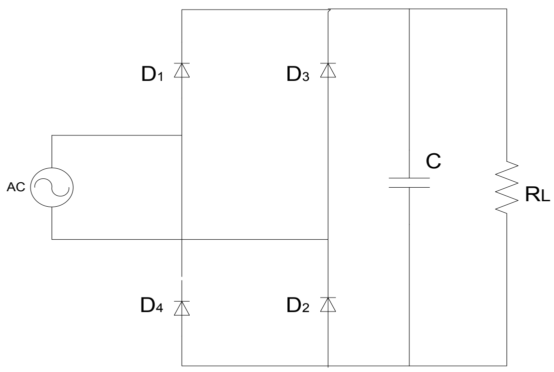

Fig. 1.5 Schematic diagram of Full Bridge Rectifier [18]

To obtain the DC output voltage, first diode D_1 and D_2 are turned on, hence we will get. The positive cycle, later when diodes D_3 and D_4 turned on will get the negative cycle

The output of full bridge rectifier is shown in figure 1.6:

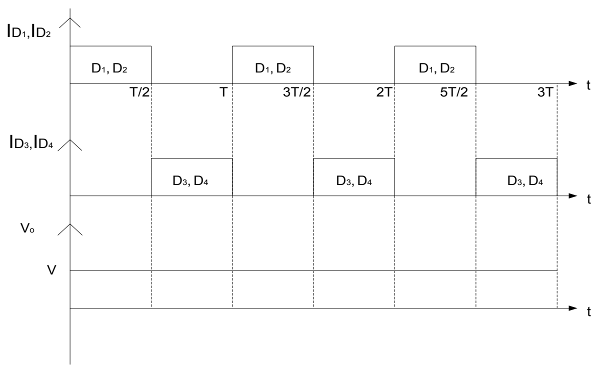

Fig. 1.6 Typical waveforms for Full Bridge Rectifier Circuit [20]

High Frequency step-up Transformer

The high frequency transformer is an integral part of the full-bridge converter. The ferrite core of high frequency transformer which operates at 100 KHz, and Transformer rated at 1KVA, The RMS Voltage of primary and secondary windings are 8V and 26V

A transformer is a power converter that transfers electrical energy from one voltage level in to another. A transformer

ISSN: 2278 – 7798

consists primary and secondary winding mounted on a core. The transformer works on Faraday's law i.e. when an alternating voltage is applied to the primary coil, an alternating magnetic field is created around this coil since it acts as an electromagnet. Since the secondary coil is in the alternating magnetic field, a voltage is induced into it in much the same way it does when moving a magnet (alternating magnetic field) in and out of a coil. A transformer works by inducing a voltage from the primary coil to the secondary coil.

If a load is connected to the secondary winding, current will flow in this winding, and the energy will be transferred from the primary circuit through the transformer to the load.

A transformer consists of 1 primary coil and 1 or more secondary coils wound around a single ferrite core (for low frequency the core used is normally iron and ferrite is for high frequency) Air core is used in very high frequency transformers.
The amount of voltage on the secondary coil depends on the ratio of primary to secondary turns (often just called the turn's ratio) [19]

III. PROPOSED WORK

The HV pulse which is generated at the output has the flat top and the rise and fall time is < 100 µsec. The below specification is obtained according to the available motor "MY 1020" from TNC Scooters, an ElectriCruz Inc. company

Parameters	Values
Input Voltage	12 V_{dc}
Output Voltage	36 V_{dc}
Output Current	35.6 Amp
Pulse width	0.5 to 1.5ms
Time Period	20 ms
Ripple	< 5%
Efficiency	≥ 95%

IV. SIMULATIONS

The simulation of the proposed paper is carried out using MATLAB software. The battery fed drive for electric vehicles using full-bridge DC-DC converter with a RCD snubber is also simulated. The simulations are performed with following parameters and the design procedure is explained above

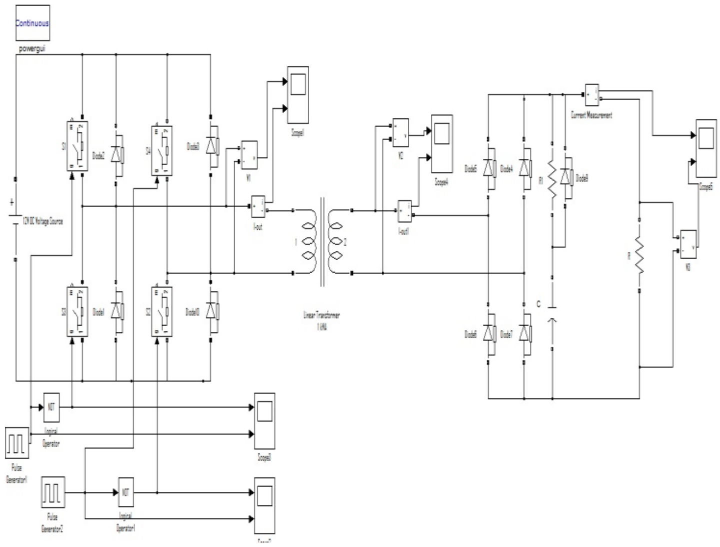

Fig 1.7 Simulation circuit of full-bridge DC-DC converter with RCD snubber circuit

V. FULL BRIDGE DC-DC CONVERTER OPERATINGPRINCIPLE

Show the operation waveform of the full-bridge DC-DC converter. We divided one cycle of switching into four operation modes and operation of individual modes are described as below-

The full bridge converter is a versatile regulation topology that can be used for various power conversions. It provides high power handling, stability and all round symmetry. When a high frequency transformer is used with this topology it not only saves weight but also provides an efficient way of stepping up voltage and transferring large amounts of power [17] and [18]

The full bridge DC-DC converter comprises of four semiconductor switches, a high frequency transformer that feeds into a rectifier circuit.
To achieve the transfer of power from the input to the output, **ideal** switches S1-S4 are switched at a high frequency. The switching sequence is in four modes described [20]

Mode 1: When switches S2 and S3 are turned ON while switches S1 and S4 are OFF; the primary voltage is positive and the diodes D4 and D7 carry the current through to the output.

Mode 2: When all switches are OFF and during this first dead time the output current continues to flow through all 4 diodes.

Mode 3: When switches S1 and S4 are ON, while S2 and S3 are OFF. The primary voltage is reversed and diodes D6 and D5are reverse biased this causes the output current to flow through diodes D4 and D7.

Mode 4: When all switches are OFF; similar to mode 2, this is the second dead time. Again in this mode the current is carried through to the output by all four diodes.

This switching sequence described in the modes above will cause a square ac wave at the primary of the transformer.

ISSN: 2278 – 7798

This ac wave is then stepped up by the transformer. The transformer output voltage is stepped up rectified and then filtered to produce the DC output. The steady state waveforms of this type of converter operating in continuous conduction mode [16]

VI. RESULTS

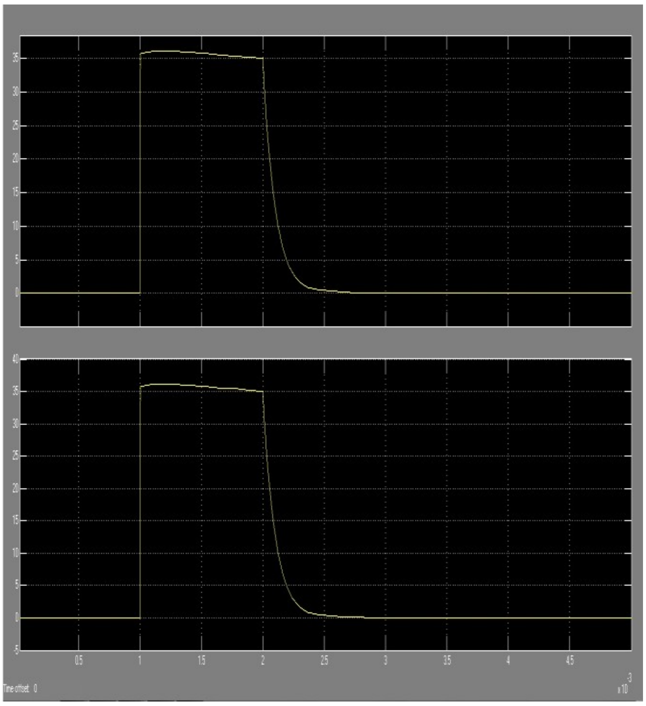

Fig 1.8 Waveform for a full-bridge DC-DC converter

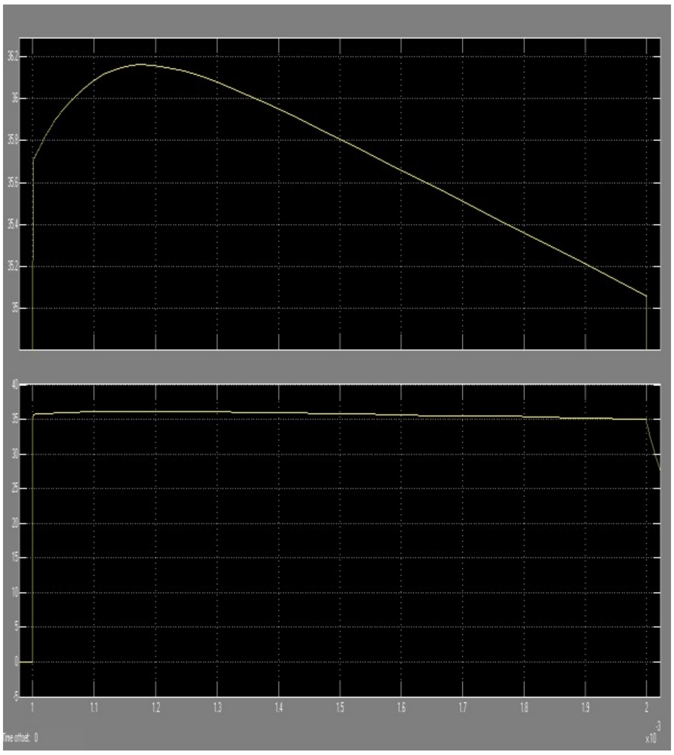

Fig 1.9 Waveform for a full-bridge DC-DC converter

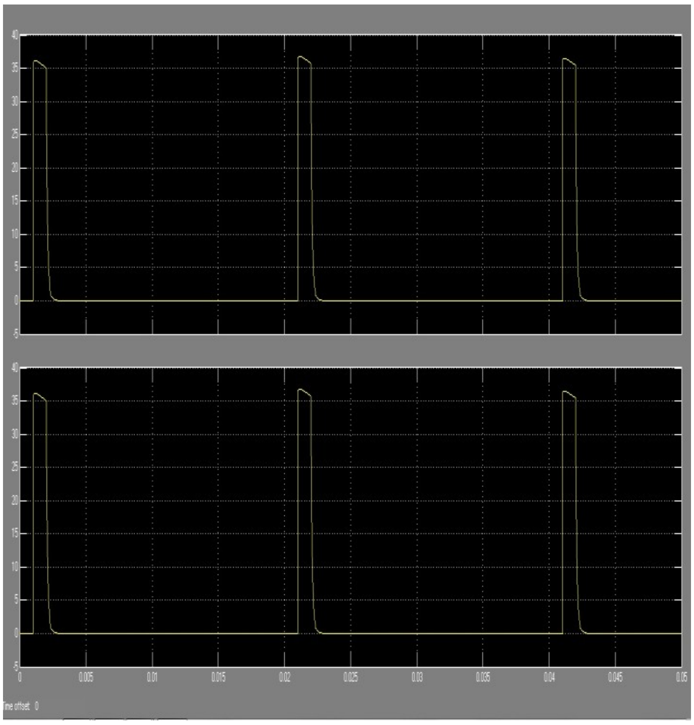

Fig 1.10 Waveform for a full-bridge DC-DC converter

VII. CONCLUSIONS

This paper describe and design on development of a DC-DC converter to convert low DC voltage (12V) into high DC voltage (36V) supplied to the electric system of electric vehicles. This converts 12V DC to 36V DC can be used by step-up transformer (ferrite core) output power up to 1.2KW. The voltage gain of the system was also satisfactory with a voltage of 36V for an input of 12V. Load current was tested only with resistive load. Apart from traditional application in dc motor drives, new applications of full-bridge DC converter include energy storage in renewable energy systems; fuel cell energy systems, hybrid electric vehicles (HEV) and uninterruptible power supplies (UPS)

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ISSN: 2278 – 7798